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P01/7700 0.00-0307465.5

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

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1. Your reference — PIERCE.FINM4.GB

2. Patent application number *(The Patent Office will fill in this part)* — 0307465.5 ✓ — 01 APR 2003 ✓

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

PIERCE, David Bland
24 Dorsington Close
Hatton Park
Warwick
CV35 7TH

Patents ADP number *(if you know it)* — 7910029001

If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention — Tube Finning Machine and Method

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

D.W. & S.W. GEE **(a/c D02702)**
1 South Lynn Gardens
London Road
Shipston on Stour
CV36 4ER

Patents ADP number *(if you know it)* — 678719600 2

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*

a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
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no

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Continuation sheets of this form	0
Description	12
Claim(s)	0
Abstract	0 8
Drawing(s)	1 & 10

10. If you are also filing any of the following, state how many against each item.

Priority documents	No
Translations of priority documents	No
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	No
Request for preliminary examination and search *(Patents Form 9/77)*	No
Request for substantive examination *(Patents Form 10/77)*	No
Any other documents *(please specify)*	None

11. I/We request the grant of a patent on the basis of this application.

Signature D.W. & S.W. GEE

Date 31.03.03

12. Name and daytime telephone number of person to contact in the United Kingdom Steven Gee 01608 661018

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Notes

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TUBE FINNING MACHINE AND METHOD

FIELD OF THE INVENTION

This invention relates to a tube finning machine and to a method of use thereof.

Typically, the finned tubes will be for use in heat exchangers, and the following description relates primarily to such use. However, the use of the machine and method for other applications is not thereby excluded.

BACKGROUND TO THE INVENTION

Often it is necessary to cool a working fluid, and it is known for this purpose to use a heat exchanger. Heat exchangers often comprise one or more metallic tubes suspended between two tube plates. The working fluid to be cooled, which may for example be water or oil, flows through the tubes, whilst the coolant passes around and between those tubes, the working fluid giving up its latent heat to the tubes and thus to the coolant.

The effective surface area of a tube can be enlarged in order to increase the heat transfer, as by the addition of one or more annular extended surface members or fins in thermal contact with the outer surface of the tube. Such finned tubes are particularly useful if the coolant has a low viscosity, and if the coolant is a gas, such as air.

The performance of a heat exchanger in part depends upon thickness of the wall of the tubes, the degree of thermal contact between the tubes and the fins, and to the total area of the fins. In general, a thinner tube wall and a better thermal contact between the tubes and the fins will increase the heat transfer from the working fluid to the

fins, and a greater surface area of the fins will increase the heat transfer into the coolant.

Each tube of the heat exchanger can have independent fins mounted thereupon, so that each finned tube is substantially thermally independent of the other tubes in the heat exchanger. Alternatively, the separate fins of adjacent tubes can be replaced by "common-fins" i.e. fins which engage (and interconnect) several tubes. Typically, a common-fin takes the form of an extended plate having several apertures, each aperture being adapted to receive a respective tube, the plate-like common-fin being in simultaneous thermal contact with several tubes, and being adapted to transfer the heat from all of the tubes to the coolant across the full area between the tubes. An array of tubes to which are mounted a plurality of multi-apertured common-fins is referred to herein as a "fin block", though in other documents it is also referred to as a "coil block" or "block fin".

DESCRIPTION OF THE PRIOR ART

US patent 3,733,673 discloses a machine for fitting several fins to one or two tubes at the same time. The fins are arranged in a cartridge, and held along their top and bottom edges. Each fin has a number of apertures therein which are sized and shaped to correspond closely with the outer periphery of the tubes to be fitted thereinto. The machine is pneumatically actuated and can drive one or two tubes at a time though the aligned apertures in the fins. Following insertion of the fin or fins, the machine can subsequently be used to insert one or two further tubes into respective apertures of the fins, until all of the tubes have been inserted thereinto.

Another machine for finning the tubes of a heat exchanger is disclosed in WO02/30591. That machine also utilises a

cartridge into which the fins are loaded prior to being driven onto the tubes.

A machine for making fin block (though as with the machine of WO02/30591 it can also apply individual fins to individual tubes) is disclosed in WO96/35093. That machine utilises a linear motor to drive a fin (or common-fin) onto one or more tubes.

All of the above documents disclose the forcing of the tubes through the (stationary) fins, and/or the forcing of fins onto (stationary) tubes. In all cases, it is necessary that the tubes do not buckle or deform during the finning operation, and this places a limit on the minimum wall thickness of the tubes and the degree of thermal contact between the tubes and the fins.

As above indicated, to facilitate greater heat exchange it is desired to reduce the thickness of the tube walls and also to increase the contact between the tubes and the fins. Satisfying the latter desire results in an increase in the frictional resistance between the tubes and the fins during relative movement, so that a greater force is required to apply the fins to the tubes. Satisfying the former desire results in a tube which is more likely to buckle or deform when the greater force needed to apply the fins to the tubes is imparted to it. Accordingly, when using the prior art machines it is necessary to compromise somewhat on heat exchange capability.

SUMMARY OF THE INVENTION

The present invention seeks to reduce or avoid the problems associated with the prior art machines and methods described above, and in particular to provide a tube finning machine, and a method of finning the tubes of a heat exchanger, which

avoids or reduces the above-stated problems and need to compromise on heat exchange capability.

According to the present invention therefore, there is provided a tube finning machine having a base, first mounting means for mounting at least one tube upon the base, second mounting means for mounting a number of fins upon the base, at least one of the first and second mounting means being movable relative to the base, characterised by tensioning means for applying a tensile force to at least part of the tube(s) whilst the fins are being applied thereto.

The present invention therefore applies a tensile force to all or part of the tube during the finning operation, whereas with the prior art machines the force upon the tubes is solely compressive. The tensile force will reduce or eliminate the compressive force acting along the longitudinal axis of the tube(s) and so reduce any tendency of the tube(s) to buckle or deform during the finning operation.

Preferably, the first mounting means is located adjacent one end of the tube(s), and the tensioning means is connected adjacent to the other end of the tube(s). Preferably also, the tensioning means includes a centraliser secured to the (or each) tube, the centraliser being connected to a drive means by which tension can be applied to the tube by way of the centraliser.

Desirably, the centraliser has a tapered leading end to facilitate passage of the centraliser, and subsequently the tube, through the fins.

Preferably, and in common with many prior art designs, the fins each have an aperture preformed therein for receiving each tube. Desirably, the aperture is surrounded by a

collar which can facilitate thermal transfer between the tube and fin.

It will be understood that the present invention is directed to fins which are a force fit onto the tubes, so that the cross-sectional dimension of the aperture (or collar) is formed to be slightly smaller than the cross-sectional dimension of the tube. This will ensure that when the fin is fitted to the tube there is a good thermal engagement therebetween. The invention is expressly not related to machines in which the apertures in the fins are initially larger than the tubes, and in which the tubes are subsequently expanded by a bulleting operating into engagement with the fins. The use of a bulleting operation is highly disadvantageous, and places additional restrictions on the tubes and the fins.

Preferably, the second mounting means is substantially fixed relative to the base, so that the fins are maintained substantially stationary relative to the base during the finning operation, and the tube(s) are driven to move relative to the base and tubes. In alternative embodiments the second mounting means (and therefore the fins) are movable relative to the base, and in yet further alternative embodiments both of the first and second mounting means (and hence both of the tubes and fins) are movable relative to the base.

In embodiments in which the first mounting means is movable, the tube(s) can be driven to move relative to the base and to the tubes solely by the tensioning means, i.e. the tubes are pulled through the fins. Alternatively, a drive means is provided which acts upon the first mounting means, so that the tubes can be simultaneously pulled by the tensioning means and pushed by the drive means.

Desirably, the centraliser is secured to the tube by way of a lip formed at the end of the tube. Desirably also, the

first mounting means includes a mandrel which is located within the tube and which engages the lip, the lip being located, and preferably secured, between the mandrel and the centraliser. Preferably, the centraliser and mandrel have cooperating threads by which they may be screw-fitted together. The mandrel may be a close fit within the tube, i.e. there may be only small difference between the cross-sectional dimension of the mandrel and the cross-sectional dimension of the tube (perhaps 0.1 mm or thereabouts). Such a small difference would allow the mandrel to be moved into and out of the tube without undue difficulty, but would enable the mandrel to support the tube against any tendency to buckle or deform (notwithstanding the expectation that such tendency is unlikely in practice).

The drive means preferably includes a resilient biassing means imparting a compressive force to the mandrel and to the tube. Desirably, the mandrel carries a collar, preferably a movable collar, which in use engages the end of the tube opposed to the lip. Accordingly, a pushing force can be imparted to the tube by way of the mandrel and collar in addition to the pulling force provided by the tensioning means.

Desirably, the tensioning means includes a second drive means which causes the tensioning means to move so as to maintain tension in the tube during movement thereof. The drive means and the second drive means can be interconnected or can operate separately but cooperatively.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described, by way of example, with reference to the accompanying drawing, which shows a schematic view, partly in section, of the important components of the tube finning machine according to the

invention, and which also shows a tube and a set of fins prior to the operation of the machine.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The machine, only a small part of which is shown in the drawing, has a first mounting means 10 by which the tube 12 may be mounted upon the base of the machine (not shown). The machine also has a second mounting means (not shown) for mounting the fins 14 upon the base of the machine.

The second mounting means may be a cartridge or other carrier for the fins 14, which provided support for the fins and ensures that they adopt their chosen relative positions upon the tube 10. In this embodiment the fins 14 are maintained stationary relative to the base during the finning operation and so the first mounting means 10 (and the tube 12) is movable relative to the base and to the fins. In other embodiments the second mounting means (and hence the fins) are movable relative to the base and the first mounting means is fixed relative to the base, and in yet other embodiments both of the first and second mounting means are movable relative to the base.

In common with prior art arrangements, each fin 14 has an aperture 16 through which the tube can be passed, the aperture being surrounded by an annular collar 20. The function of the collar is to increase the thermal transfer between the tube and the fins in the assembled heat exchanger, and the presence of a collar is typical with metallic fins. To ensure a good thermal contact between the tube 12 and the fins 14 the edge 22 of each collar 20 is slightly smaller than the outer wall of the tube 12, so that the fins are a force fit upon the tube 12. The heat exchanger designer therefore can take advantage of the resilience of the collar to ensure that when the fin has been applied in its chosen position upon the tube the collar

will grip the tube and ensure a good thermal contact therebetween.

A drive means (not shown) is provided to drive the tube 12 through the fins 14, it being necessary to stretch the collar 20 (and in particular the edge 22 thereof) as the fins 14 engage the tube 12. In common with prior art machines, the drive means can be a drawbench (utilising a chain drive for example), a linear motor, another electrically powered drive means, or a pneumatic or hydraulic drive means.

According to the present invention, the drive means is connected to the leading end of the tube 12. Specifically, the drive means is connected to a pull rod 24 which can be passed through the apertures 16 in the fins to engage a centraliser 26. The pull rod 24 is connected to the centraliser by way of its threaded end 28 being inserted into the correspondingly threaded well 30 formed in the centraliser.

The centraliser is in turn connected to the leading end of the tube 12 by way of a mandrel 32 which can be fitted into the tube 12, the mandrel having a threaded well 34 to receive the correspondingly threaded boss 36 of the centraliser 26.

The leading end of the tube 12 has an inwardly-deformed lip 40 formed thereon, which lip may be produced during manufacture of the tube, or as a preliminary process step before installation of the tube 12 on the tube finning machine.

The opening 42 surrounded by the lip 40 is smaller than the mandrel 32 so that the mandrel cannot pass therethrough. The opening 42 is, however, larger than the boss 36, so that the boss 36 can be passed therethrough to engage the mandrel. Accordingly, when the centraliser 26 has been

secured to the mandrel 32 the mandrel and therefore also the tube 12 can be pulled by its leading end by way of the centraliser 26.

It will be understood that the form of the lip is not important provided that it can serve to secure the centraliser to the leading end of the tube. Thus, the formation of the lip into a flange perpendicular to the axis of the tube as with the lip 40 is not necessary, and the lip can instead taper inwardly. It is also not necessary that the whole of the periphery of the tube wall be deformed into the lip, but instead the lip can comprise separate inwardly deformed sections of the tube wall, if desired.

It can be arranged that the drive means is only connected to the leading end of the tube 12, so that the only force acting upon the tube is a tension force applied to its leading end, and it is solely pulled through the apertures 16 in the fins 14. Preferably, however, and as shown in the present embodiment, the first mounting means 10 is also driven, so that the tube 12 is both pulled and pushed through the apertures 16 in the fins 14.

Since at least part of the force acting upon the tube 12 is a tensile force, the tendency of the tube to buckle or deform during fitment of the fins is reduced over the prior art arrangements in which all of the force upon the tube acts in compression. The wall of the tube 12 can therefore be made of thinner (and perhaps softer) material than is possible with the prior art machines, without need to reduce the thermal engagement (and thus the frictional resistance to relative movement) between the tube and the fins. The heat transfer capability of the assembled finned tube can therefore be increased.

In the embodiment shown, the mandrel 32 carries a collar 44 which is movably mounted on the mandrel, and can be secured at any position therealong. The collar 44 is positioned so

that it will engage the trailing end of the tube 12 when the mandrel 32 engages the lip 42 (the movable collar allowing the same mandrel to be used with different length tubes).

The first mounting means 10 also includes a housing 46 within which the mandrel 32 is mounted, the end of the mandrel 32 being slidably located within the housing 46 and engaged by a compression spring 50. The housing 46 is connected to a push rod 52 which in turn is connected to a further drive means (not shown), or if desired to the same drive means as the pull rod 24.

Though not shown in the drawing, in practice the components of the machine will be coaxial (as represented by the dashed lines), so that the mandrel 32 can lie within the tube 12 and the tube 12 is aligned with the apertures 16 in the fins 14 and can be connected to the pull rod 24.

To operate the machine, the tube 12 is fitted over the mandrel 32, and is secured thereto by way of the centraliser 26 being screwed into the well 34 of the mandrel. The fins 14 are installed on the machine, usually in a cartridge or other carrier as above described, with the apertures 16 aligned with the longitudinal axis of the tube 12. The pull rod 24 is then passed through the apertures 16 and connected to the centralise. If desired the centraliser can be connected to the mandrel 32 and the pull rod 24 at the same time, for example by the use of opposite threads on the boss 36 and in the well 30 of the centraliser. The drive means is then actuated to cause the pull rod 24 and centraliser 26 to pull the tube 12 through the apertures 16 in the fins 14. At the same time, the drive means (or the secondary drive means if applicable) drives the first mounting means so as also to push the tube 12 through the apertures 16 in the fins 14.

It will be seen that the centraliser 26 has a tapered leading end, the purpose of which is to cause the collars 20

of the fins 14 to stretch as the centraliser 26 is forced therethrough. The provision of a taper is preferred over a flat leading end since it allows the gradual expansion of the collar to the size required to pass the tubes and consequently a gradual increase in the force required, rather than a sudden increase in the force required as would be the case if the collar was required to pass a step. In addition, the trailing end of the centraliser is shaped at 54 to closely match the leading end of the tube 12, so that the collar cannot fall into a gap between the centraliser and the tube.

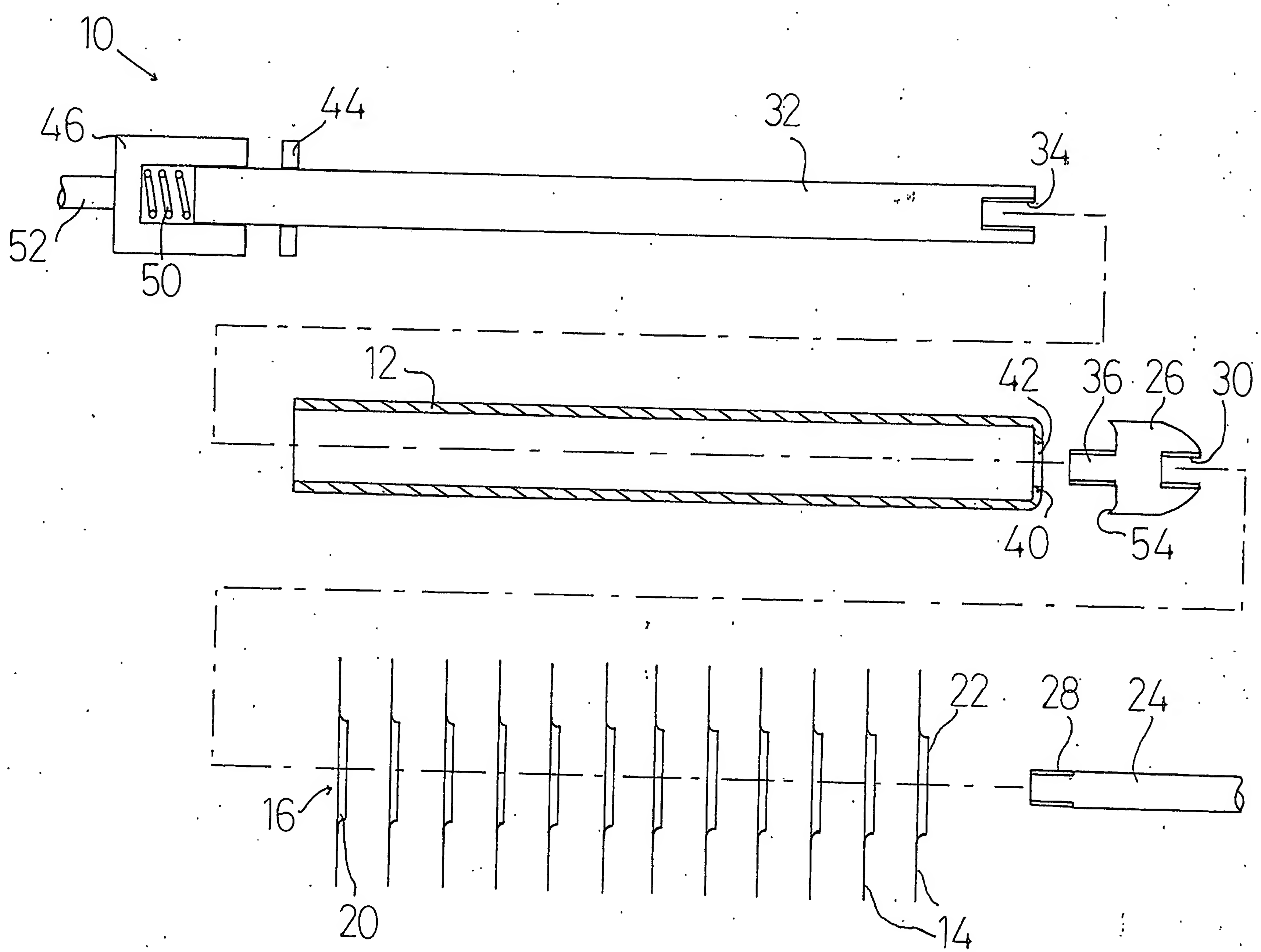
It will be understood that there is an indirect mechanical link between the push rod 52 and the tube 12, i.e. the compressive force acting upon the tube is determined by the spring 50. The rating of the spring, and the degree of initial compression imparted thereto, can be chosen to suit the tube 12 and the fins 14, it being appreciated that a weaker spring, with less initial compression, will impart only a small compressive force to the tube 12, so that almost all of the force applied to move the tube will be tensile. On the other hand, a strong spring, with a greater amount of initial compression, will impart a large compressive force to the tube 12, so that a large proportion of the force applied to the tube is compressive.

In the drawing, the cross-sectional dimension of the mandrel is shown as being somewhat smaller than the cross-sectional dimension of the tube, so that the mandrel will be a relatively loose fit inside the tube 12. However, since the presence of a mandrel is required in the invention, it would be possible to exploit the mandrel by making it only slightly smaller than the tube, these parts perhaps differing in cross-sectional dimension by around 0.1 mm or so. Whilst this would likely make it more difficult to insert the mandrel into the tube the mandrel could act to resist any tendency of the tube to deform or buckle during the finning operation. Such a machine could be used with

tubes having very thin walls, which walls could be very effective in transferring heat to the fins.

Whilst the drawing shows only one tube and a number of fins, the invention could equally well be used to make a fin block in which a number of tubes are driven through the apertures in a number of common-fins. The machine could have a number of pull rods each acting together so that some or all of the tubes of the fin block are finned together, or it could have just a single pull rod so that one tube is inserted into the common-fins at a time.

It will be understood that the invention could equally well be utilised in a machine in which the fins are moved relative to tubes which are fixed relative to the base. In such embodiments, the "pull rod" 24 would not move significantly during the finning operation, but would be connected to the base of the machine. As the fins are forced over the tube the pull rod 24 would act to hold the tubes stationary and so maintain a tensile force in all or part of the tube, the spring 50 providing the desired compressive force at the other end of the tube.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